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Engine Combustion Test using Algae Biofuel with Nanofluid

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The research attempts to analyze the influence of *S. Marginatum* algae biodiesel, used in a diesel engine with additives. Transesterification was used to prepare biodiesel from microalgae to mix with standard diesel at a rate of 20% (vol.) called B20. The nanofluid Al_2O_3 was prepared and tested along with B20 under different loads at a speed of 1500 rpm in a direct ignition diesel engine for their combustion characteristics. It is concluded that fuel mixtures of Al_2O_3 nanofluids confirmed better combustion on a CI engine compared to B20 mix.

Keywords: Algae biomass, Al_2O_3 nanoadditive, Biodiesel, Blending, Combustion

Introduction

Renewable fuels add more to the fossil fuel reserves. Biodiesel will be used as a synthetic fuel to meet current and future energy demands. Compared to diesel, biodiesel emits low carbon and smoke emissions which decreases climate change.[1] Studies have indicated that lower heating value and high emissions of NOx restrict biodiesel usage in the diesel engine. Earlier studies suggested that biodiesel mixed with nanoparticles could boost engine efficiency and at the same time leading to a significant decrease in engine exhaust emissions. Earlier studies showed that adding biodiesel additives would boost engine efficiency while reducing NOx emissions but increasing gradually other emissions.[2] Earlier studies have illustrated that biodiesel mixtures with additives and nanoparticles found more benefits than their tidy form. A few studies have addressed the effects of biodiesel blends with various additives on a CI engine. The current study examines the results of biodiesel blends on a CI engine with Al_2O_3 nanofluids applied to diesel. The research work focuses on the impact of a CI engine's combustion parameters.

Materials and Methods

Preparation of Biodiesel and Nanofluids

Alkaline transesterification technique was used to produce SMME (*S. Marginatum* Methyl Ester) by taking the raw algae oil. Methoxide solution mixing is the primary step in SMME production using ultrasonicator. It is then heated with crude algae oil for around 60 minutes up to 65°C. It was left for settling and separation of glycerol layer in 24 hours happens due to its higher density. Upper layer is crude biodiesel. The crude biodiesel is then washed with distilled water until the wastewater shows no colour change with phenolphthalein indicator. Crude biodiesel was then kept overnight with anhydrous sodium sulfate for dehydrating the residual water content. Blending of biodiesel along with Al_2O_3 nanofluids additives was done using ultrasonicator.[3] Three fuels were prepared and tested. One is B20 formed by 20 % blending of algal biodiesel with petro-diesel. The other two are addition of 0.1 and 0.2% (vol./vol.) of Al_2O_3 nanofluid to B20. For several days the formulated nanofluids have remained highly stable. ASTM specifications are used to assess the properties of test fuel blends as shown in Table 1. The specifications of nanofluids are shown in Table 2. There is no particulate sedimentation in the prepared nanofluids.

Nanoparticle Size Analysis using XRD

XRD analysis was performed with X'pert powder XRD method, PANalytical X-Ray diiffract meter with Co-Kα radiation in the range of 10–90°, to analyse the crystal structure, size and purity of the purchased Al_2O_3 nanoparticles. To assess the crystalline size an X-Ray beam was passed through a nanoparticle sample with a wavelength of 0.15 nm. The XRD patterns of the purchased Al_2O_3 nanoparticles specifically are shown in Fig. 1. All peaks in XRD

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Table 1 — Physio-chemical properties and details of Al_2O_3 nanoparticle

Properties	ASTM D975	ASTM 6751	Diesel	B100	B20	B20+0.1Al_2O_3	B20+0.2Al_2O_3
Density at15 °C (kg/m^3)	—	861–901	851	891	989	986	986
Kinematic viscosity at 40°C (mm^2/s)	2–4.2	3.6–5.1	2.7	4.85	3.3	3	3.1
Calorific value(kJ/kg)	—	—	44841	42053	41204	45364	45529
Cetane number	41	48	47	64	53	52	54
Flash point(°C)	53	102	65	129	98	83	83
Fire point(°C)	—	—	71	137	111	110	111

Table 2 — Details of Al_2O_3 nanoparticle

Company	Sigma Aldrich
Specific Surface area	40 m^2 /g
Number of CAS	1344-28-1
Molecular Weight	101.96
Color	White
Linear Formula	Al_2O_3
Size of particle	<50nm
MDL number	MFCD00003424

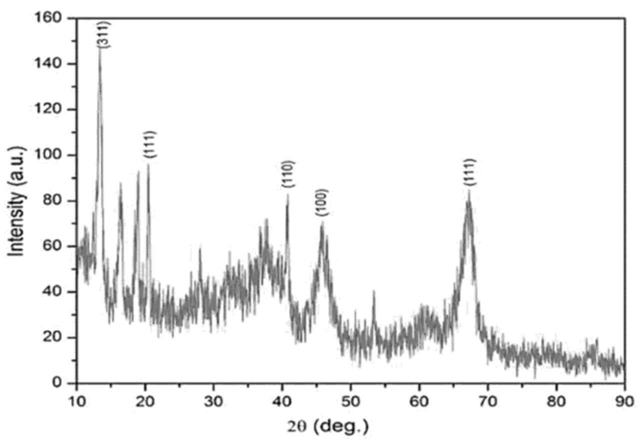

Fig. 1 — XRD patterns for Al_2O_3 nanoparticle

patterns clearly demonstrate good crystal structure of both nanoparticles and detect no peaks of impurities. The XRD test results therefore show that the purity of purchased nanoparticles exceeds 99%. The Al_2O_3 nanoparticles obtained sizes, 50 nm, and 27 nm, respectively.[4]

Experimental Setup

A single-cylinder diesel engine and an eddy current dynamometer with an exhaust gas analyser were included in the analytical test setup. The impact of the real-time sensors is processed with a data acquisition system on the computer. In this analysis the variations in output and exhaust emissions are investigated. Digital tachometer is being used to measure engine rpm. Form K thermocouples are used to measure the temperature of the exhaust gas. The data acquisition method based on LabVIEW is used to track the data in real time.[5]

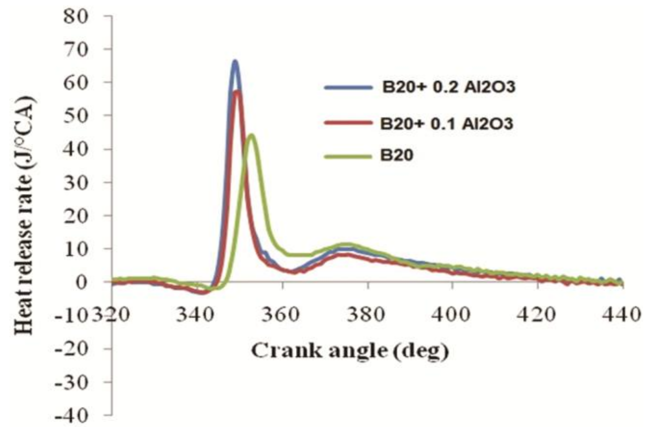

Fig. 2 — Variation in heat release rate with changing crank angle

Results and Discussion

Heat Release Rate (HRR)

The HRR for Al_2O_3 nanofluids B20, 0.1 and 0.2 at 100% load is shown in Fig. 2. Premixed phase for Al_2O_3 nanofluids is found to be higher than B20. Owing to the high viscosity of the B20 less fuel is being required for the premixed phase and most of the combustion occurs in the diffusion combustion process. More diffusion oxidation is also led to elevated smoke emissions. Higher HRR in premixed combustion is observed with Al2O_3 nanofluids as compared to B20 due to lower biodiesel viscosity. In the premixed process, higher HRR of Al_2O_3 nanofluids results in greater peak pressure.[6]

Cylinder Pressure (CP)

The cylinder pressure variation at 100% load according to the angle of the crank is shown in Fig. 3. For B20, lesser air-fuel mixture is formed during the pre-mixed combustion process that leads to lower heat release and therefore lower peak pressure. During the diffusion combustion process, the heat release is delayed and it produces even more heat, which leads to lower peak pressure, higher EGT and reduced energy transfer to useful work. With processing of Al_2O_3 nanofluids,

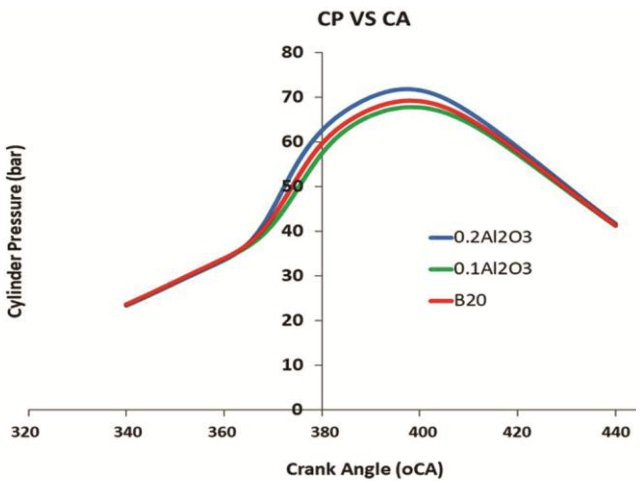

Fig. 3 — Variation of cylinder pressure with varying crank angle

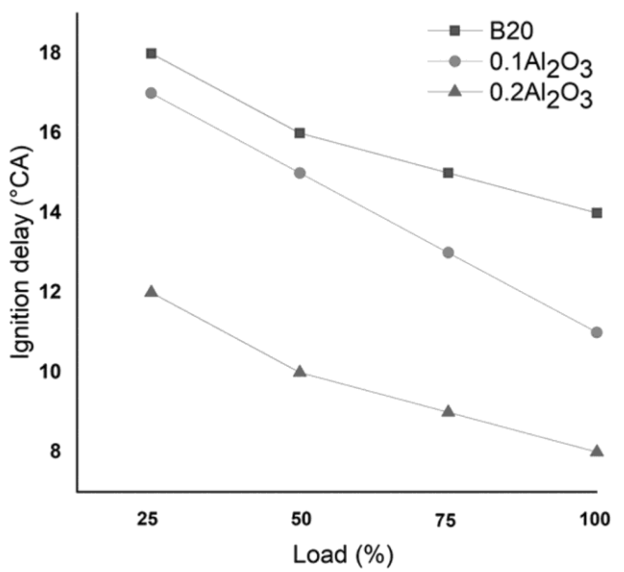

Fig. 4 — Variation of ignition delay with varying load

ignition improved and thus high thermal release occured in which cylinder peak pressure induced proximity to operation of Al_2O_3 nanofluids.[7]

Ignition Delay (ID)

The difference in load and ignition delays is shown in Fig. 4. The B20 shows prolonged delays in the ignition compared to nanofluid Al_2O_3 pre-mix, due to decreased volatility, high viscosity and density. This leads in inadequate atomization as well as vaporisation. Ignition delay decreased at all charges with B20 leading to enhanced fuel properties like lower viscosity that reduces the delay in physical ignition. Ignition delay for Al_2O_3 nanofluid pre-mix and B20 is 12° CA, 11° CA, and 9° CA at a load of 100%, respectively.[8]

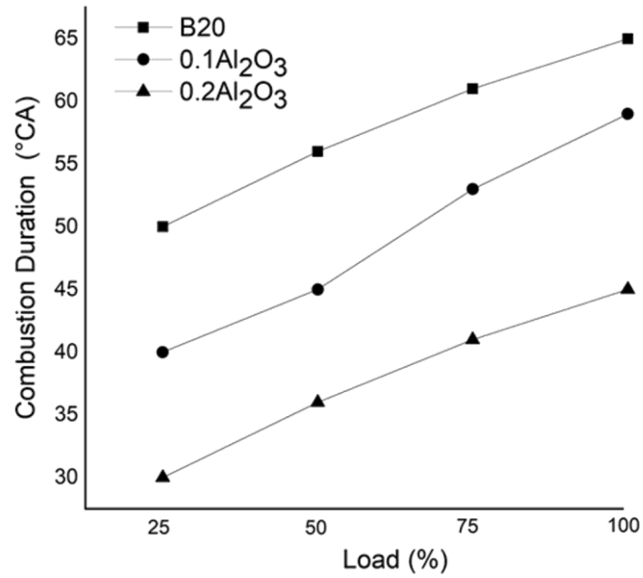

Fig. 5 — Variation of combustion duration with varying load

Combustion Duration (CD)

The difference in the time of combustion with load for the different test fuels are shown in Fig. 5. Due to poor fuel spray characteristics of B20, Combustion duration (CD) is longer indicating inferior combustion. Combustion duration for B20 and Al_2O_3 nanofluid pre-mix is 67°CA, 58°CA, and 47°CA respectively, at 100% load. Combustion duration is lower for Al_2O_3 nanofluid pre-mix in comparison to B20. This is due to better combustion of Al_2O_3 nanofluids as a result of modified fuel properties such as lower density and viscosity.

Conclusion

In the present study, the combustion characteristics of a single-cylinder engine running on B20 blend of *S. Marginatum* algae, and its pre-mix with 0.1 and 0.2 Al_2O_3 nanofluid were investigated. The effects of various parameters, such as HRR, cylinder pressure, percentage mass burnt, delay in ignition and duration of combustion was studied. Adding Al_2O_3 nanoparticles to B20 fuel and running the engine at constant speed and constant variable load indicated enhancements in engine combustion as load power increased and the ignition delay as well as the combustion duration decreased.

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